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Engaging Utilities and Regulators on Transportation Electrification

An analysis of electrification of passenger vehicles identified three areas where engagement with utilities and their regulators would help to advance policy and practice on plug-in electric vehicles: making a better policy case, improving regulatory incentives and adopting smart charging technology.

Nancy E. Ryan and Luke Lavin

I. Introduction

Across the U.S., there is an increasingly clear public policy case for electrifying passenger transportation. Plug-in electric vehicles (PEVs)[1] can be a near-term option for improving local and regional air quality.[2] A growing chorus of studies finds that electrifying passenger transportation is essential to strategies to reduce greenhouse gas (GHG) emissions to very low levels by mid-century.[3] Although PEV sales are growing rapidly, their adoption will likely need to increase by an order of magnitude over the coming decade to reach levels consistent with public policy goals.

Electric utilities are critical actors in shaping the speed, cost, and environmental impacts of transportation electrification. Through outreach, education, and direct incentives, utilities can accelerate PEV adoption. Through rate designs and programs, utilities can encourage charging behavior that reduces rates for other customers,

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provides value to shareholders, minimizes costs to vehicle owners, and reduces criteria pollutant and GHG emissions. To date, many utilities have taken a cautious, reactive approach to vehicle electrification. This article argues for engaging utilities to develop a more proactive approach, based on the potential nearer- and longer-term benefits that PEVs provide to utility customers and shareholders, PEV owners, and society at large.

To explore the utility and societal case for transportation electrification, this article draws from the results of recent studies conducted by Energy and Environmental Economics (E3). Section II establishes the public policy case for longer-term electrification of passenger vehicles in the U.S. Section III describes the potential economic benefits of PEVs to utility customers, shareholders, and vehicle owners. Section IV examines how changes in rate design and utility programs can help utilities achieve these benefits. Section V distills key issue areas for engaging utilities and regulators on PEVs going forward.

II. The Public Policy Case for PEVs

The public policy case for PEVs is mainly grounded in their environmental benefits — zero or near-zero tailpipe emissions and, with a shift to non-fossil-fuel sources of electricity generation, low overall emissions. In regions of the U.S. that have difficulty attaining compliance with federal air quality standards, such as southern California, accelerating PEV adoption is a near-term strategy for moving toward compliance.[4] Over the longer term, electrifying passenger transportation is likely to be a critical element of efforts to minimize the risks of climate change. This section focuses on the latter, drawing on a study E3 conducted as part of the UN-sponsored Deep Decarbonization Pathways Project (DDPP).[5]

To date, many utilities have taken a cautious, reactive approach to vehicle electrification.

The premise of the DDPP, a collaborative effort of research teams from the 15 largest GHG-emitting countries, was to ask each country team to develop technologically feasible pathways for reducing energy-related CO_2 emissions to levels consistent with a 2 degree Celsius (2 °C) increase in global average surface temperatures. E3 led the U.S. DDPP study, in collaboration with Lawrence Berkeley National Laboratory and the Pacific Northwest National Laboratory.

Electrifying passenger transportation was necessary to meet a 2 °C 2050 target in all of the scenarios E3 examined as part of this study. The logic is straightforward. Passenger vehicles account for just under 20 percent of U.S. CO_2 emissions, and their emissions currently exceed the total, economy-wide 2050 target.[6] CO_2 emissions from mobile sources like passenger vehicles cannot be controlled, which means that passenger transportation will need to shift to other, lower-carbon energy sources. Biofuels are likely to have higher value as a low-carbon fuel in other sectors. The remaining low- to zero-carbon primary energy sources — renewable energy, nuclear, and fossil fuels with CO_2 capture — all must be converted to electricity before they can be consumed by end users. Although, in principle, this low-carbon electricity can be further converted into hydrogen to power fuel cell vehicles, in most of the cases E3 examined PEVs were the dominant passenger vehicle technology.[7]

Electrification of the passenger vehicle fleet, as well as electrification of other traditional uses of oil and gas, drives a significant increase in electricity demand in the U.S. between 2030 and 2050, shown in Figure 1 for a ''high renewables'' case. Because of dramatic improvements in residential and commercial end-use efficiency,

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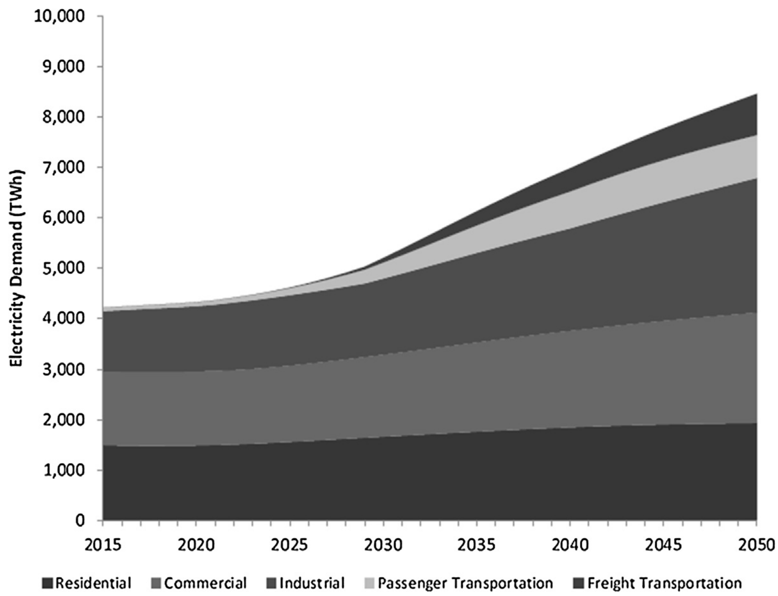

Figure 1: Electricity Demand by End Use Sector, E3 U.S. DDPP Report's ''High Renewables'' Case

most of the growth in electricity demand results from new kinds of loads (e.g. for industrial customers) or new kinds of customers (e.g. PEVs). By the mid- to late-2030s, passenger transportation is an important electricity consumer. In this case, the freight transportation sector also becomes a significant source of electricity demand by 2050, though this is primarily through production of ''electric fuels'' (e.g. hydrogen, synthetic natural gas).

The necessary timing of PEV adoption to meet a 2 °C CO_2 target by 2050 is governed by stock-turnover dynamics for passenger vehicles. Because passenger vehicles have 10–15-year lifetimes, annual sales — the number of new vehicles purchased and old vehicles replaced — are a small share of the total fleet. Even rapid growth in sales requires many years to have a significant impact on the composition of the vehicle fleet. In all of E3's cases, a nearly full turnover of the U.S. passenger vehicle fleet is necessary to achieve the target by 2050 (Figure 2). With this constraint, more rapid growth in PEV adoption could wait until the early 2020s. However, by the end of the decade PEVs would need to account for almost all new vehicle sales.

Such a dramatic scale-up of PEV adoption suggests the need for more proactive nearer-term policy and regulatory innovations and engagement with utilities, in key leading states, to support longer-term electrification of passenger transportation. As described in the next section, these efforts can

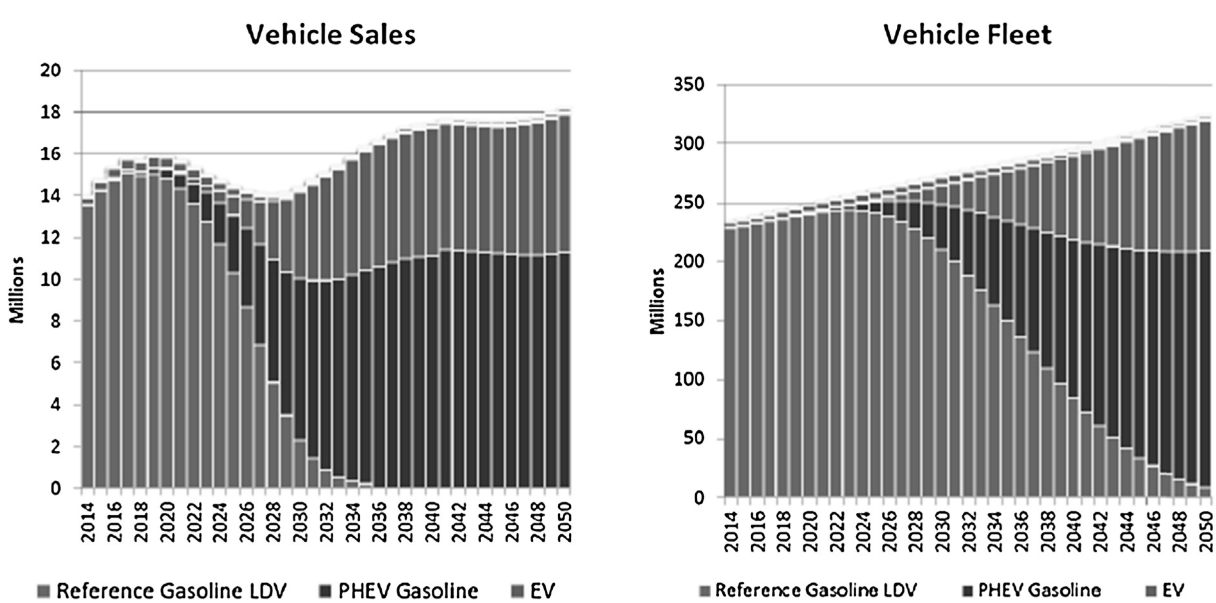

Figure 2: Light-Duty Vehicle Sales and Vehicle Fleet, E3 U.S. DDPP Report's ''High Renewables'' Case

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be oriented around the potential benefits that PEVs provide to utility customers, shareholders, and vehicle owners in the near to medium term.

III. Potential PEV Benefits to Utility Customers, Shareholders and Vehicle Owners

PEVs offer different kinds of potential benefits to utility customers, shareholders, and vehicle owners in the near to medium term. For utility customers, PEVs can lower rates by improving asset utilization and decreasing costs. For shareholders, they can increase returns and present a new source of growth and investment. PEV owners realize fuel cost savings, through improvements in vehicle efficiency, and may also benefit from utility and other incentives. This section provides an overview of potential nearer-term PEV benefits from each of these different perspectives.

A. Benefits to utility customers

Electricity demand varies significantly across seasons, kinds of days (weekdays, weekends, holidays), and over the course of a day. The example in Figure 3, for the California Independent System Operator (CAISO) region, illustrates the large differences in demand that occur between the highest and lowest load days, and

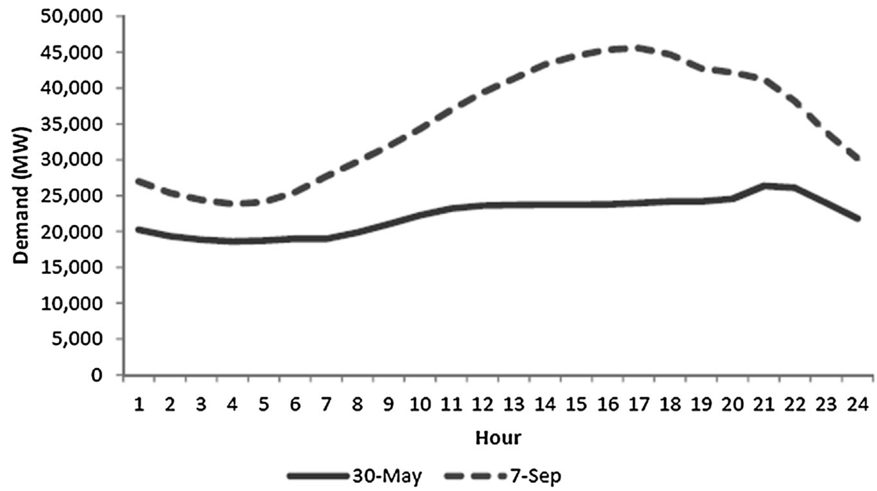

Figure 3: CAISO Control Area Highest and Lowest Load Days, 2011

between nighttime and daytime demand on high-load days. Because electricity infrastructure — power plants, transmission lines, distribution systems — is built to meet peak demand, large differences in the timing of consumption mean that this infrastructure is frequently not used at its full capacity, resulting in higher costs per kilowatt-hour (kWh) of electricity sales.[8] PEVs often have considerable flexibility in when they are charged, providing an opportunity to incentivize charging at off-peak times when capacity utilization is low.[9] If they are charged off-peak and improve capacity utilization, PEVs lower costs, which translates to lower rates for customers. If PEVs are charged during local or total system peaks, they trigger investments in transmission and distribution infrastructure and procurement of new generating capacity, raising costs for customers. For utilities, a goal should be to ensure that the net benefits (incremental benefits minus incremental costs) to customers are positive.

PEVs are a new source of revenue for utilities, but charging them increases generation (capacity and energy) and infrastructure (transmission and distribution) costs. For PEVs to provide benefits to *all* utility customers the revenues collected from PEV owners for charging must exceed the cost of serving the new load. In a recent study for the California Electric Transportation Coalition (CalETC), E3 assessed the net benefits of PEV adoption under California's Zero Emission Vehicle Program (the ZEV Program)[10] using standard regulatory cost benefit tests. Typically used to assess the cost-effectiveness of energy efficiency programs relative to investments in new power plants, these tests provide a window into the impact of new PEV load from a variety of perspectives.

Figure 4 addresses the question of whether a representative California utility's customers are

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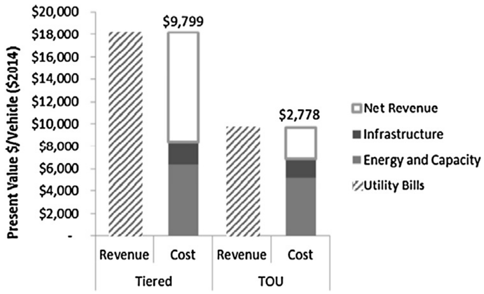

Figure 4: Utility Net Revenues from PEV Adoption, E3/ICF CalETC Study[11]

better or worse off as a result of growing PEV charging load. Simply put, this comparison shows whether PEV customers contribute more revenue to utilities than the cost of serving them. The figure shows estimated utility revenues, costs, and net revenues associated with PEVs under two typical residential tariffs — tiered and time-of-use (TOU) rates[12] — with net revenues ranging from $2,788 to $9,799 over the life of the vehicle, depending on rate structure. Revenues and net revenues are higher under tiered rates, but lower under TOU rates as PEV owners are allocated a larger share of cost savings through lower off-peak rates. In both cases, there are positive net revenues to the utility, part or most of which can then be shared with customers as reductions in rates. Utilities and their regulators can shape both the size of net benefits and how they are allocated.

B. Benefits to utility shareholders

In an era of declining utility sales, where growth in energy efficiency and behind-the-meter generation are posing a threat to the traditional utility business model, PEVs represent a new opportunity for growth and innovation. Growth in electricity demand from PEVs can benefit utility shareholders in multiple ways. Part of the potential cost savings from improved capacity utilization, described in the previous section, can be shared with shareholders. For instance, an earnings sharing mechanism, commonly used in performance-based ratemaking, would allow a portion of utility cost savings to translate into higher return on equity.

Shareholders also benefit from the need for nearer- and longer-term investment associated with PEVs. In the near term, utilities may see significant opportunities to invest in charging infrastructure, depending on regulatory rules. In the longer term, sustained growth in PEVs will require upgrading and modernizing distribution systems. Greater use of information and communications equipment in distribution operations will allow for more optimal use of PEVs as a flexible load, providing cost savings to customers over the longer term. These longer-term savings, combined with nearer-term savings from improved capacity utilization, provide a source of downward pressure on rates that can offset the costs of increased investment.

Potential shareholder benefits have, by and large, not yet spurred sufficient interest for utilities to develop proactive strategies around PEVs. Many utilities remain focused on short-term, traditional areas of business that have greater revenue and regulatory certainty. In a number of states, utilities do not have clear incentives for PEVs, and the value proposition to shareholders thus lacks a more solid grounding. Many of the capital investment opportunities associated with PEVs are predicated on sustained growth in PEVs, creating a chicken-and-egg problem. Overcoming these obstacles requires changes in regulation. These changes should not focus narrowly on providing incentives for growth, but rather on the quality of growth and value to customers.

C. Benefits to vehicle owners

For PEV owners, benefits are largely from fuel cost savings and utility incentives. Savings on gasoline are a significant benefit to PEV vehicle owners, which must be balanced against the higher upfront cost of the vehicle. These fuel savings result primarily from the higher energy efficiency of PEVs. For travel in electric mode, PEV owners generally have to purchase around 60 to 70 percent less energy per mile than would be required for a conventional gasoline vehicle.[13] Although electricity is often slightly more expensive than gasoline per unit of energy,[14] this significant improvement in efficiency leads to operating cost savings.

The fuel cost savings to vehicle owners comprise a large share of the net societal benefits from PEVs. Figure 5, also from the CalETC study, illustrates this for residents of a representative California utility's service territory, again using tiered and TOU rates. While PEVs do provide environmental and energy security benefits for a state's residents generally, the vast majority of benefits are from gasoline savings and federal incentives that accrue to vehicle owners. Net societal benefits are higher when PEVs are served on TOU rates because of the cost savings (productivity improvements) from improved capacity utilization.

Vehicle owners can also benefit from utility outreach programs and direct incentives. Even in cases where PEV adoption would save customers money, they may choose a conventional car or light truck because of the uncertainty surrounding costs and charging options. Because of the complexity of retail rate structures, many customers are not likely to be able to calculate their annual cost savings from a PEV; nor are many customers aware that they could, in principle, charge a PEV with a level 1 charger without any changes in their electrical wiring.[15]

Utilities may also provide direct incentives to PEV owners, either for charging equipment or for the vehicle itself. Georgia Power, for instance, currently provides rebates on residential, workplace, and community charging equipment.[16] Revenues to support both customer awareness and direct incentive programs can be justified through potential cost savings to customers. The regulatory principle for this — the net benefits test — is based on the notion that existing customers should be willing to share some of the cost savings that result from new customers to attract those customers.

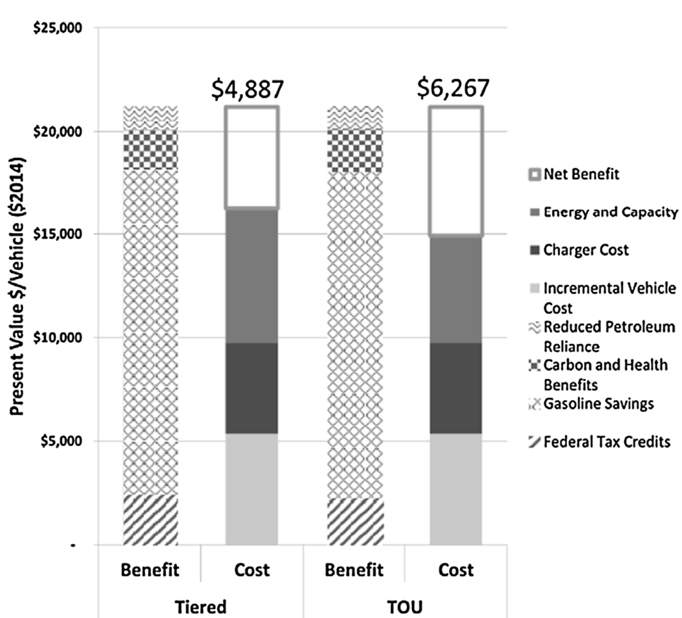

Figure 5: Illustrative Societal Net Benefits from PEV Adoption, E3/ICF CalETC Study

IV. Achieving Consumer and Shareholder Benefits of PEVs

The financial benefits of PEVs — either in the nearer or longer term — will not necessarily materialize as a matter of course. Achieving them will, in many cases, require regulatory changes that better align the interests of utility customers, utility shareholders, and vehicle owners. In particular, it will require efforts to encourage vehicle owners to charge in a way that maximizes the net benefits of PEVs to the electricity system (''smart charging''). This section describes how smart charging can limit cost increases associated with PEVs in the near term, and improve utilization of renewable energy generators in the longer term.

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4.1. Nearer term: limiting cost increases through TOU rates

Much of the initial concern with PEV cost impacts has focused on distribution systems. For instance, as California prepared for the new generation of PEVs to begin arriving in 2010, a major uncertainty was whether the distribution system, especially in older residential neighborhoods, would be able to support charging. Utilities worried about adverse effects on safety and reliability, as well as the potential expense of spreading the costs of any necessary upgrades across their entire customer base. The California Public Utilities Commission (CPUC) ordered the utilities to track PEV-related upgrade expenses in order to provide an empirical basis for setting policy on upgrade costs. Reports subsequently submitted to the agency show that so far these costs have been negligible.[17] Going forward, however, PEV charging will eventually strain the distribution system and drive higher costs if not properly managed.

E3 and ICF's analysis in the CalETC study examined the distribution system impacts of PEV charging under a range of assumptions for PEV adoption in California through 2030. To determine when residential distribution circuits would start to become overloaded due to PEV charging, E3 and ICF used actual data on the topology of participating utilities' distribution systems, projected load growth from PEV charging and simulated PEV deployment based on the geographic pattern of hybrid vehicle ownership. Even under rapid PEV adoption (7 million PEVs in 2030), few major residential distribution system upgrades were needed until the 2030 timeframe. As shown in Figure 6, projected upgrade costs were more than 60 percent lower when PEV owners were assumed to be mostly served on TOU rates than if they took service on flat or tiered rates.

Improvements in charging technology are enabling more price-responsive charging among PEV owners. For instance, most PEVs have on-board chargers that allow charging times to be programmed either within the vehicle or remotely via an Internet-connected device. In other words, to take advantage of off-peak TOU rates vehicle owners do not need to plug in their vehicle at the beginning of an off-peak period; instead they can keep their vehicle plugged in and program it to only charge during the off-peak period. With these kinds of enabling charging technologies, some of the available evidence thus far suggests that PEV customers can respond to TOU rates.[19]

4.2. Longer term: improving renewable energy utilization

Wind and solar energy are becoming an increasingly important part of the U.S. generation mix, and their shares are expected to continue to grow. Wind and solar output is both variable and uncertain, requiring changes in power system operations to accommodate them. Adding progressively more wind and solar energy to a region's generation mix changes net load — the difference between total generation output (gross load) and the output of non-dispatchable generators, such as wind, solar, and nuclear. As the

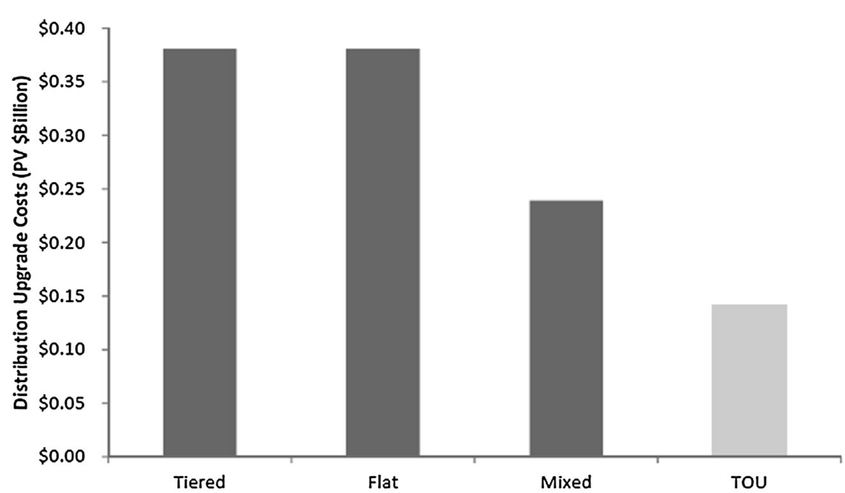

Figure 6: Present Value of Estimated Distribution System Upgrade Costs, E3/ICF CalETC Study[18]

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penetration of non-dispatchable resources grows, these changes can become significant. The system operator's challenge is to meet net load with dispatchable resources and price responsive demand. As a flexible, potentially price responsive, and potentially dispatchable load, PEVs may be part of the solution to this challenge.

In a recent study for California's five largest utilities (''RPS study''), E3 examined the integration challenges of a higher renewable portfolio standard (RPS) for California in 2030.[20] Solar, as the state's most abundant renewable resource, is key to this challenge. As **Figure 7** illustrates, while adding solar generation reduces the need to run gas-fired ''peaker'' plants to meet the gross system peak on hot summer days (left-hand panel, ''highest load day''), it also creates the potential for over-generation and steep ramps on days with abundant sun and relatively low consumption (right-hand panel, ''highest ramp day''). Over-generation, also referred to as negative net load, occurs when non-dispatchable generators are producing more energy than the electricity system can absorb.

Faced with over-generation conditions, and absent other solutions, system operators would need to curtail renewable generators to maintain reliability. Significant levels of curtailment increase the costs of renewable energy and introduce contractual risks for renewable energy developers and utilities that could hamper the growth of renewable industry. E3's RPS study identified several solutions to mitigate over-generation. One such solution is to exploit the flexibility of loads such as PEVs.

The challenge of balancing power systems with high penetrations of solar energy turns the conventional system planning problem upside down. Instead of reducing flexible loads during daytime hours to respond to supply shortages, system operators need flexible loads that can ramp up during the middle of the day in order to mitigate solar over-generation. One way to accomplish this is through smart charging of PEVs at workplaces and other locations where they are parked for many hours during the day. Because they do not vary from day to day, or within pre-defined periods, TOU rates are an overly blunt instrument to incentivize charging during periods of over-generation. Dynamic rates, which vary by hour to reflect changes in marginal costs, could be a more appropriate tool.

Figure 8 shows a hypothetical example that illustrates how dynamic rates can be used to enlist PEV owners in reducing over-generation. The figure is based on analysis E3 prepared in support of San Diego Gas & Electric Company's (SDG&E's) application to the CPUC for approval of a pilot program to test

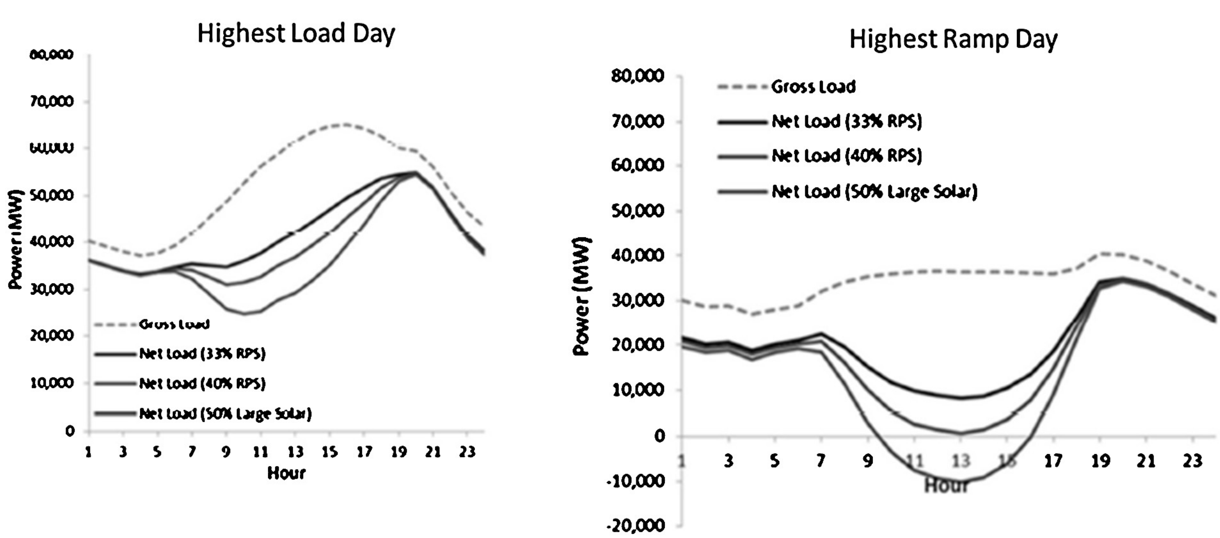

Figure 7: Gross and Net Load for Highest Load and Ramp Days in CAISO System in 2030, E3 RPS Study

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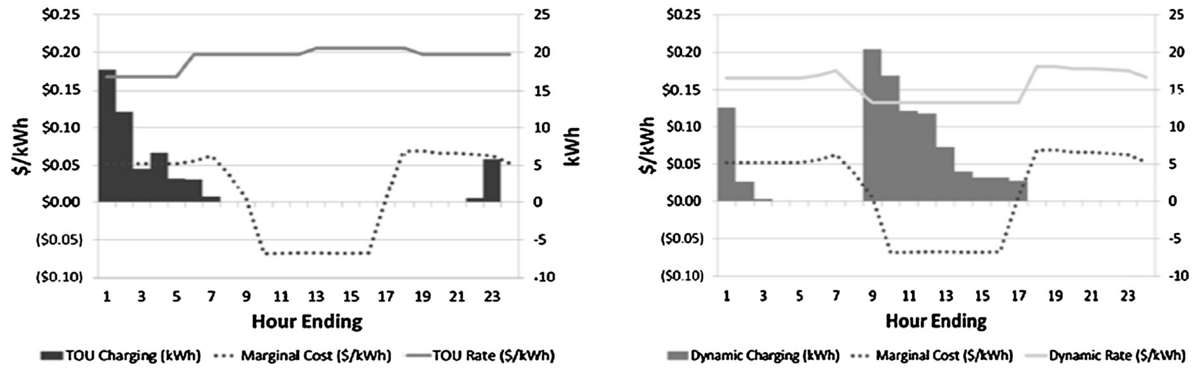

Figure 8: Hypothetical PEV Charging under TOU and Dynamic Rates, E3 Support to SDG&E Dynamic Rates Pilot Application

the effectiveness of dynamic rates for PEV charging; using a custom smartphone application, participating customers may actively manage charging or set parameters to respond passively to price signals.[21] With dynamic rates, customers are incentivized to charge during periods when the marginal cost of energy is lowest, which coincide with periods in which the share of output from non-dispatchable generators is highest. The figure shows a day with significant solar over-generation, indicated by the negative marginal cost of energy during midday hours. In the left-hand panel, the PEV customer faces a TOU rate schedule and charges mostly late at night. In the right-hand panel, the customer is enrolled on a dynamic rate that tracks the marginal cost of energy.

The above example assumes that PEV customers will, in fact, respond to price incentives by shifting charging to over-generation hours where the marginal cost of energy is low. SDG&E's proposed pilot program is designed to test this responsiveness. If PEV owners prove to be price responsive, improved utilization of solar energy — effectively, more solar output (kWh) per unit of investment costs ($) — will benefit all utility customers. If PEV owners are relatively price unresponsive individually, other strategies, such as creating the market and regulatory space for load aggregators to manage PEV loads, may be a better solution. Pilot programs like SDG&E's are an important testing ground for these questions.

4.3. Future study: understanding regional renewable integration challenges

More generally, the challenges of wind and solar over-generation vary across climate regions in the U.S. Figure 9 shows simulated weekly gross and net load shapes for four different regions in the Western U.S. under a scenario in which renewable energy accounts for 27 percent of the region's generation mix in 2022. The figures are drawn from E3 and DNV GL's study for the Western Interstate Energy Board (WIEB) on the adequacy of natural gas infrastructure to meet changing electric sector needs in the western U.S.[22] The solar-dominant Desert Southwest (bottom left) shows a pattern of over-generation (shaded area) similar to California (top left). This regular, diurnal pattern can potentially be mitigated by shifting daily charging schedules for PEVs via smart charging. Renewable generation and net load are very different in the Rocky Mountain (top right) and Pacific Northwest (bottom right) regions, where onshore wind is the dominant renewable resource. In those regions the system operator must be able to respond to occasional large ramps as the wind dies or picks up speed. Stationary storage, perhaps using recycled batteries from PEVs, may be a more suitable integration solution in these areas. This spatial variability in renewable energy integration challenges suggests the need for nearer-term, state-specific research and pilots to better understand the potential effectiveness of solutions like PEVs.

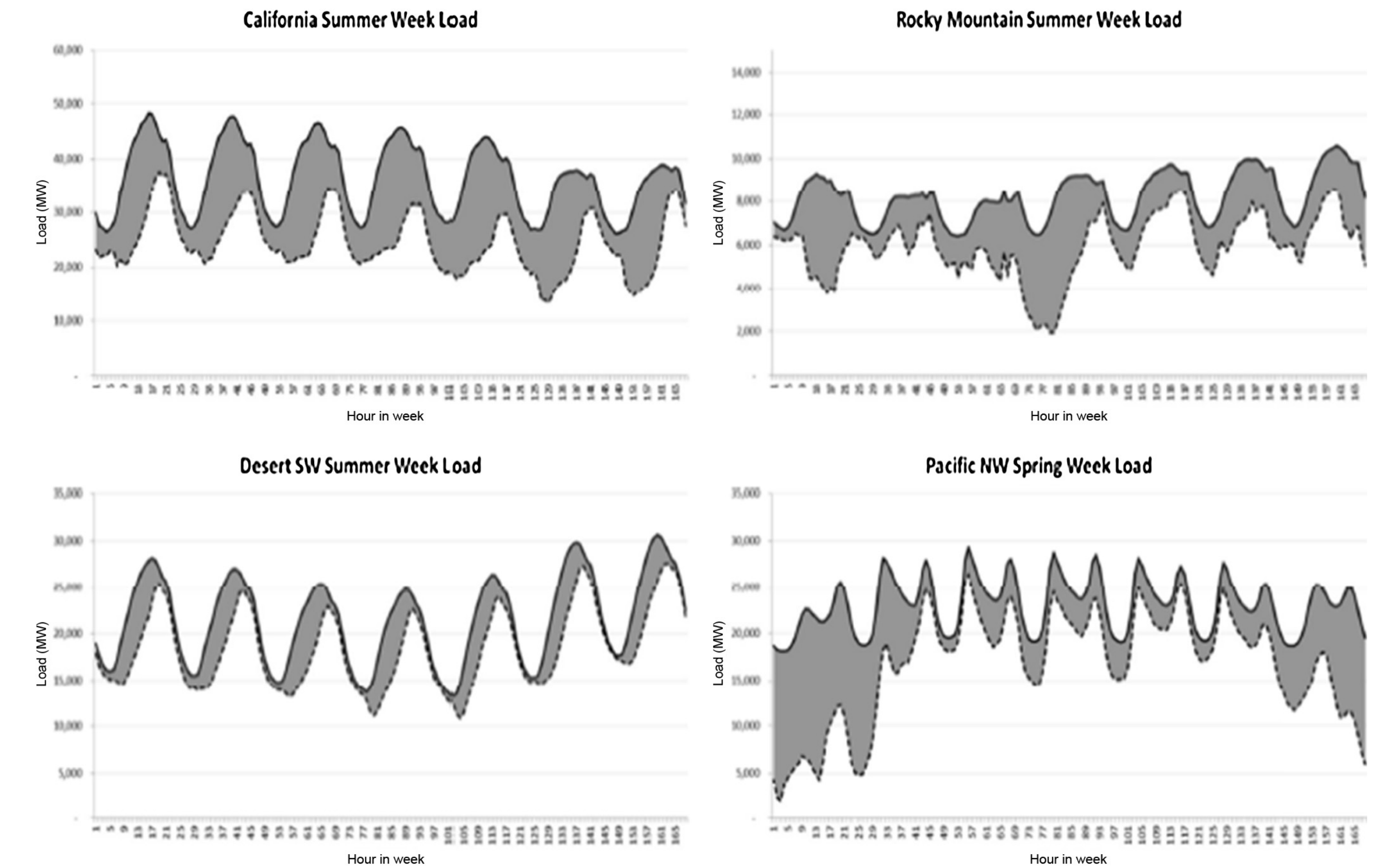

Figure 9: Gross and Net Load Shapes from Four WECC Regions under High Renewables (27 percent WECC RPS) case in 2022, E3 and DNV GL WIEB Study

5. Key Issues for Utilities and Regulatory Commissions

Innovations in regulatory policy and utility practice are essential to realizing the potential benefits of PEVs. This article has identified three areas where engagement with utilities and their regulators would help to advance policy and practice on PEVs.

Better understanding and acting on the public policy case for electrifying passenger transportation

Electricity systems across the U.S. are, in general, not well prepared to support or accommodate a large-scale electrification of passenger transport, beginning within the next decade, which would be consistent with a national 2050 GHG emission reduction target. Better preparation begins with a longer-term perspective that takes into account how the electric sector will evolve over time and the needs and benefits of PEV charging load. Given the large uncertainty surrounding the energy sector, this longer-term perspective is critical for improving nearer-term investment, regulatory, and policy decision-making. It provides a foundation for identifying and addressing potential obstacles to transportation electrification within the next decade, enhancing the chances of a smooth transition later on. For policymakers and regulators, a longer-term perspective would also provide opportunities to better link other nearer-term public policy goals (e.g. air quality improvements) with longer-term GHG goals. For automakers and PEV buyers, a long term perspective can help shape product design and influence charging behavior as the market for PEVs develops and consumer preferences are formed.

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Improving regulatory incentives and increasing regulatory certainty, to better capture potential PEV benefits to utility customers, shareholders, and vehicle owners

New PEV loads may already be able to provide benefits to utility customers and shareholders, and these benefits will grow with increased adoption. However, utilities frequently lack the regulatory incentives to take a more strategic approach toward PEVs. Proactive strategy is necessary to support innovations in a number of areas —customer engagement, business models, ratemaking, system planning and distribution operations — that influence the speed and scale of PEV adoption, as well as and its overall cost (or cost savings) impact. Utilities and regulators will need to work together to ensure that current incentive frameworks are not an impediment to PEV adoption.

In structuring incentives, regulators should seek to encourage utilities to maximize the charging flexibility of PEVs in ways that increase capacity utilization and limit the need for distribution upgrades. This requires balancing three interests: (1) cost savings to utility customers, which can be shared with PEV owners and utility shareholders; (2) utility support for PEV owners (e.g. customer engagement, rate designs, direct incentives), which encourages adoption and potentially greater cost savings; and (3) performance incentives to utility shareholders, so that shareholders have an economic motivation for making a tradeoff between improved capacity utilization and increased distribution system investment.

For both charging facility construction and distribution upgrades, regulatory uncertainty is a barrier to more efficient investment. For instance, state regulators have taken very

different approaches to utility ownership and operation of charging infrastructure, and in many states rules for cost recovery are not yet clear. The lack of efficient investment, in turn, has the potential to create infrastructure bottlenecks for PEV adoption. Addressing this uncertainty should be a priority for the regulatory community.

Given the diversity of models for regulating electric utilities across the U.S., solutions to regulatory incentive and uncertainty issues associated with PEVs are likely to be state specific. There are, however, many opportunities for regulators and utilities in different states to learn from one another. Government agencies and the nonprofit and consulting communities can play an important role in facilitating these exchanges.

Smart charging is critical for achieving nearer and longer-term PEV benefits

A large portion of the benefits of PEVs to utility customers and to the environment stems from their charging flexibility. TOU rates can be an effective, ''off-the-shelf'' tool for incentivizing charging during off-peak periods. For many utilities, however, implementing TOU rates for residential customers requires changes in rate design, an expansion in rate options, and in some cases new metering infrastructure. It also requires outreach to ensure that potential PEV customers are aware that they are eligible for alternative rates, and education to ensure that they understand the implications of different rate options. Many customers have neither the time nor ability to calculate their total electricity costs under different rates. Utilities need to ensure that they have practical and clear rate design options, and then work with their customers to help them better understand their options.

In the longer term, the promise of PEVs is in their potential to charge flexibly according to the electricity system's need, particularly for balancing wind and solar generation. It is still not clear what combination of changes in retail rate design and

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business and regulatory models will be necessary to enable this flexibility. Pilot programs like SDG&E's present windows of opportunity for learning that should not be missed. Early adopters are often willing to participate in pilot programs, more so if PEV buyer incentives are linked to participation. If utilities and regulators focus now on learning-by-doing, the longer-term value proposition of PEVs will be considerably enhanced.

Appendix. Description of E3 Projects Surveyed and Cited

Deep Decarbonization Pathways Project (DDPP)

The United Nations' Deep Decarbonization Pathway Project (DDPP) is a group of research teams for the 15 largest GHG-emitting countries (Australia, Brazil, Canada, China, France, Germany, India, Indonesia, Japan, Mexico, Russia, South Africa, United Kingdom, United States; together representing over 70 percent of global emissions) tasked with developing technologically feasible pathways for reducing their country's GHG emissions to levels consistent with a 2 degree Celsius (2 °C) increase in global average surface temperatures. E3 led the U.S. DDPP team in collaboration with Lawrence Berkeley National Laboratory and the Pacific Northwest National Laboratory. The U.S. team developed four technologically feasible scenarios consistent with a mitigation target of 1.7 tons CO_2/capita in 2050: a central (mixed) case, a high-renewables case, a high-carbon-capture-and-storage (CCS) case, and a high-nuclear case. These scenarios and the broader DDPP project will inform proceedings at the 21st session of the Conference of the Parties to the United Nations Framework Convention

on Climate Change in Paris in 2015.

Web site:

- https://ethree.com/publications/index_US2050.php

California Transportation Electrification Assessment (CalETC Study)

The California Electric Transportation Coalition (CalETC) contracted E3 and ICF to characterize the benefits of electrification technologies on behalf of its members, including PG&E, SCE, SDG&E, SMUD, and others. This report is meant to coordinate a move toward transportation electrification among CalETC's members and quantify the benefits of multiple transportation electrification pathways California could follow. The study will inform utility strategy on PEVs in California and related rulemaking processes.

Web sites:

- http://www.caletc.com/wp-content/uploads/2014/09/CalETC_TEA_Phase_1-FINAL_Updated_092014.pdf;
- http://www.caletc.com/wpcontent/uploads/2014/10/CalETC_TEA_Phase_2_Final_10-23-14.pdf

Investigating a Higher Renewable Portfolio Standard in California

E3, in collaboration with ECCO International and DNV KEMA, conducted a study on various higher Renewable Portfolio Standard (RPS) scenarios for California on behalf of the five largest California utilities (LADWP, PG&E, SMUD, SDG&E, and SCE). The study asks what the requirements, operational challenges, potential solutions, costs, and consequences of integrating 50 percent RPS by 2030 in California are (California currently has a 33 percent RPS requirement by 2020). Challenges specifically explored by the model include downward ramping capability, upward ramping capability, minimum generation flexibility, and peaking capability – all potential concerns for system reliability under high renewable generation scenarios. The study finds these

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challenges can be overcome, but proper planning and policy become much more instrumental in doing so at higher RPS targets.

Web site:

- https://ethree.com/documents/E3_Final_RPS_Report_2014_01_06_with_appendices.pdf

SDG&E Electric Vehicle-Grid Integration Pilot Program

The California Investor Owned Utility San Diego Gas and Electric (SDG&E) hired E3 to support their application to the California Public Utilities Commission (CPUC) to conduct a vehicle-grid integration (VGI) pilot program. This program introduces hourly time-variant rates and grid-beneficial charging infrastructure to better incentivize and match PEV charging with grid benefits. E3 supported this analysis by developing a VGI cost-benefit model, and found the proposed dynamic rates offer more grid benefits and lower costs for PEV owners under base case price responsiveness assumptions. The VGI pilot has been combined with California's ongoing Alternative-Fueled Vehicle rulemaking and will be considered by the CPUC in early 2015.

Web site:

- http://www.sdge.com/regulatory-filing/10676/sdge%E2%80%99s-electric-vehicle-grid-integration-pilot-program

Natural Gas Infrastructure Adequacy in the Western Interconnection: an Electricity System Perspective (WIEB Study)

The Western Interstate Energy Board (WIEB) contracted with E3 and DNV GL to investigate the adequacy of gas infrastructure for meeting changing electric sector needs in the Western United States. The two major questions reviewed were whether natural gas infrastructure will be sufficient for meeting electric sector needs in the West over the next decade, and whether the gas system will provide sufficient short-term operational flexibility to meet electric sector ramping needs. In addition to a common case, three scenarios – high coal retirement (50 percent of remaining coal plants retired), high renewables (27 percent WECC RPS), and high export sensitivity (2.0 MMcf/d exports in Southwest, 1.5 MMcf/d exports in Northwest) – were developed. Under the scenarios examined E3 and DNV GL find it is technically feasible to meet natural gas demands and integrate higher renewable penetration; a variety of changes in how the gas system is operated can facilitate this process. These insights are meant to inform gas infrastructure development strategy in the Western U.S. and Canada going forward.

Web site:

- https://www.ethree.com/public_projects/wieb.php ■

Endnotes:

1. Throughout this paper, PEV refers to both plug-in hybrid electric vehicles (PHEVs) and full battery electric vehicles (BEVs).

2. As has been argued in a number of studies, whether and the extent to which PEVs reduce criteria pollutants (SO_2, NO_2, O_3, PM, CO) depends primarily on generation mix. In coal-dominant regions, higher penetrations of PEVs are generally thought to increase SO_2 but reduce CO and, depending on controls, NO_x and PM. For the case of Texas, see Nichols, B.G., Kockelman, K.M., Reiter, M., 2015. Air quality impacts of electric vehicle adoption in Texas. Transp. Res. D: Transp. Environ. 34, 208–218. From a forward-looking perspective, the environmental ambiguity of PEVs in coal-dominant grids is less a case against PEVs and more a rationale for reducing the environmental impacts of coal.

3. See, for example, Williams, J.H., et al., 2012. The technology path to deep greenhouse gas emissions cuts by 2050: the pivotal role of electricity. Science 335, 53–59; Wei, M., et al., 2013. Deep carbon reduction in California require electrification and integration across economic sectors. Environ. Res. Lett. 8; Long, J., et al., 2011. California's Energy Future: A View to 2050. California Council on Science and Technology, Sacramento; Yang, C., et al., 2009. Meeting an 80% reduction in greenhouse gas emissions from transportation by 2050: a case study in California. Transp. Res. D: Transp. Environ. 14, 147–156; Melaina, M., Webster, K., 2011. Role of fuel carbon intensity in achieving 2050 greenhouse gas reductions within the light-duty vehicle sector. Environ. Sci. Technol. 45, 3865–3871; International Energy Agency, 2009. Transport, Energy, and CO_2: Moving Towards Sustainability. OECD/IEA, Paris; National Research Council, 2013. Transitions to Alternative Vehicles and Fuels. The National Academies Press, Washington, DC).

4. For example, the California Air Resources Board has determined that, to attain ozone standards by 2032, Nitrogen Oxide (NOx) emission reductions in the South Coast Air Basin and San Joaquin Valley Air

Pollution Control Districts will require virtually all light, medium, and heavy-duty vehicles to be zero or near-zero emission.

5. Sustainable Development Solutions Network (SDSN) and Institute for Sustainable Development and International Relations (IDDRI), *Pathways to Deep Decarbonization* (New York and Paris: SDSN and IDDRI, 2014), http://unsdsn.org/wp-content/uploads/2014/09/DDPP_Digit_updated.pdf

6. The U.S. Energy Information Administration (EIA) estimates that light-duty vehicles accounted for 1,026 $MtCO_2$ (19%) out of a total of 5,426 $MtCO_2$ in 2014. Data are from the *Annual Energy Outlook* 2014, http://www.eia.gov/oiaf/aeo/tablebrowser/. E3 used a 2050 target of 750 $MtCO_2$ for energy-related CO_2 emissions in the DDPP study.

7. For more on these cases, see the U.S. DDPP report, http://unsdsn.org/wp-content/uploads/2014/09/US-Deep-Decarbonization-Report.pdf

8. Capacity utilization in electricity sectors is frequently measured in terms of load factor, the ratio of average to peak demand. For the average American utility, load factor has hovered around 60 percent, a relatively low level of utilization, since the late 20th century. See Edison Electric Institute, *Statistical Yearbook of the Electric Power Industry*.

9. For more information on the possibilities for and benefits of encouraging off-peak charging, see Berkheimer, J., et al., 2014. Electric grid integration costs for plug-in electric vehicles. SAE Int. J. Alternat. Powertrains 3, 1–11.

10. See http://www.arb.ca.gov/msprog/zevprog/zevprog.htm

11. The comparison in **Figure 4** is more formally known as a Ratepayer Impact Measure (RIM) Test. It is meant to answer the question of whether customers who adopt a technology or measure (e.g. PEVs, rooftop solar PV) are increasing or decreasing rates for customers of the same utility service provider who do not adopt the technology or measure. It does not directly measure broader system-wide or societal impacts, which would be appropriately accounted for using the Total Resource Cost (TRC) or Societal Cost (SC) Tests. Figure 5 displays results from a SC Test.

12. Most residential customers of California IOUs are served on steeply inclining block — tiered — rate schedules. PEV owners have the option to take service on TOU rates. Despite the fact that many California PEV owners would realize significant monthly bill savings from opting into TOU rates, most remain on standard tiered rates. See ''Application of Southern California Edison Company (U 338-E) for Approval of its Charge Ready and Market Education Programs,'' http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M127/K294/127294826.PDF

13. For instance, a conventional car with a fuel economy of 30 miles per gallon uses around 4 megajoules (MJ) of purchased energy per mile. By contrast, a comparable electric vehicle that uses 0.35 kWh per mile and has a charging efficiency of 85 percent will use 1.5 MJ of purchased energy per mile while in electric mode.

14. The average residential rate in the U.S. was $0.1188/kWh, or $0.0330/MJ, in 2012; the average price for gasoline (all grades) was $3.68/gallon, or $0.0307/MJ, in 2012. Data are from the EIA Web site, http://www.eia.gov/

15. Other studies have shown that public awareness of the availability and benefits of PEVs is a significant barrier to PEV adoption. See Committee on Overcoming Barriers to Electric-Vehicle Deployment, *Overcoming Barriers to Electric Vehicle Deployment* (Washington, DC: The National Academies Press, 2013).

16. See http://www.georgiapower.com/environment/electric-vehicles/

17. The most recent of these reports concludes that, of the approximately 100,000 PEVs in investor-owned utility territory, only 126, or 0.1 percent have required a service line and/or distribution system upgrades. See http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M143/K954/143954294.PDF. For the original decision, see http://docs.cpuc.ca.gov/PublishedDocs/WORD_PDF/FINAL_DECISION/139969.PDF. For reports filed by utilities, see http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M042/K158/42158457.PDF and http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M088/K489/88489523.PDF

18. This figure is based on the CARB Most Likely Adoption Case, or 2.2 million PEVs in 2030.

19. For instance, in the DOE-funded EV Project offered subsidies for home charging equipment to purchasers of Nissan Leaf and Chevy Volt vehicles in exchange for allowing metering of their PEV charging consumption. Variations in the tariffs available for PEV charging across the participating regions created a natural experiment to assess the impact of TOU rates on charging behavior. In Washington, DC, which did not offer TOU rates, customers charged PEVs during the early evening peak. In San Diego Gas & Electric's service territory, which had a ''super off-peak'' rate that was aggressively marketed to PEV owners, customers charged in the early morning off-peak hours. See http://www.theevproject.com/

20. See E3, ''Investigating a Higher Renewables Portfolio Standard in California,'' https://ethree.com/documents/E3_Final_RPS_Report_2014_01_06_with_appendices.pdf

21. See ''Application of San Diego Gas & Electric Company (U 902 E) for Approval of its Electric Vehicle-Grid Integration Pilot Program,'' https://www.sdge.com/sites/default/files/regulatory/VGI%20Application_FINAL.pdf

22. This study included two phases. For more on the study, and for the reports from each phase, see https://www.ethree.com/public_projects/wieb.php

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